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High speed photography equipment and specialized accelromters was purchased to obtain measurments related to blast mitigation and damage evolution in concrete systems and large scale buildings.

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cc: Sam Kiger
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Final Report

Instrumentation to Support the Mission of the National Center for Explosion Resistant Design (NCERD)

by
Sam A. Kiger[1], Ph.D., P.E. and Hani A. Salim[2], Ph.D.

Proposal No: 39358-EG-RIP
Contract No: DAAD19-99-1-0112

Thanks to a generous grant from the Army Research Lab and the University of Missouri-Columbia, two high-speed digital photography systems, a 10-channel transient signal conditioning/amplifier data acquisition system, shock isolated accelerometers, soil stress gages, air blast gages, and interface stress gages were procured to provide unique capabilities to the University of Missouri (MU) National Center for Explosion Resistant Design (NCERD) in its current and potential research and educational projects and goals.

The NCERD is currently conducting research funded by the Air Force Office of Scientific Research, the Army Corps of Engineers Waterways Experiment Station (WES), and the University of Missouri Research Board. In addition, the center has submitted a proposal to WES for the design and testing of blast retrofit walls for masonry walls and is developing a proposal to be submitted to TSWG for the design, manufacturing, and

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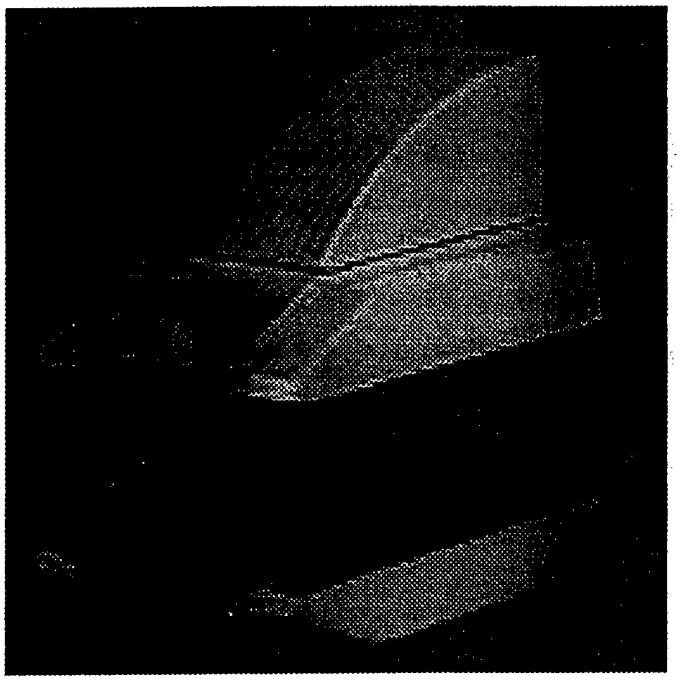
testing of a portable light-weight containment vessel for explosives, biological, and/or chemical agents.

Main Instrumentation systems purchased through this grant

Following are the main equipments obtained through the ARL funding. Additional instrumentations, but not listed here, were also purchased that supplement the main items.

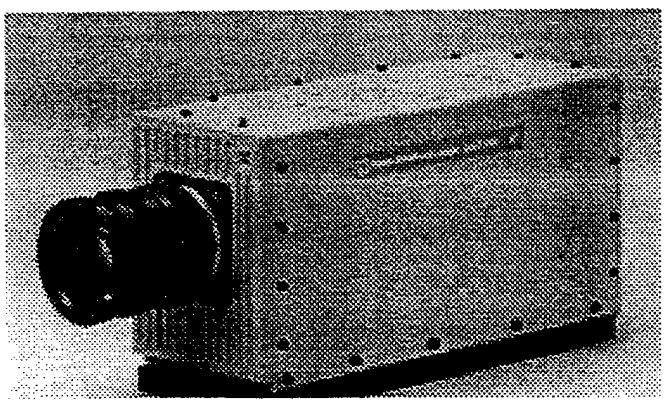


1. Ultra high-Speed Digital Photography System

The Imacon 468 Ultra High-Speed Digital Imaging System was purchased through this funding. This camera represents the absolute top end of the spectrum when it comes to high-speed motion analysis. The camera is capable of recording up to 12 frames at a rate of as fast as 200 million frames per second, with variable inter-frame delays periods. This system will enhance the modeling capabilities of the research efforts at NCERD. Behaviors such as material phase transition, crack propagation, impact and penetration, shock waves through materials, and blast environments will be better understood through the use of such system.

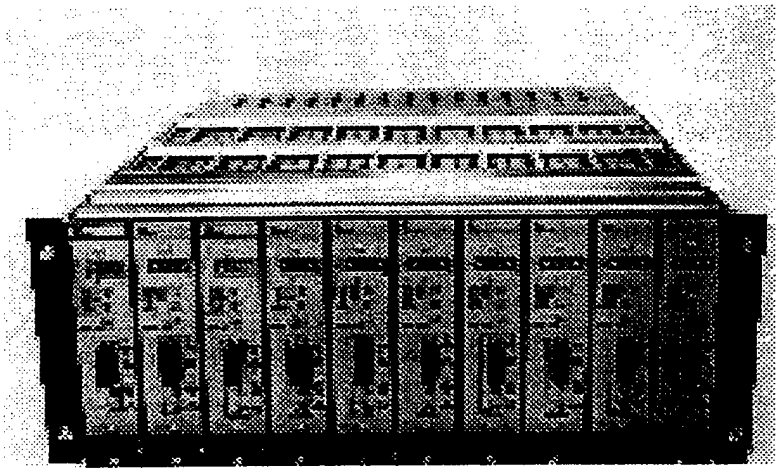
2. Moderate High-Speed Camera

KODAK EKTAPRO HG Imager, Model 2000 was also purchased through this funding. The digital



camera is capable of recording up 2000 frames per second. With a total recording time of 2.73 seconds (5,461 images) this camera allows us to capture the delayed structure response under blast/impact loading. Another valuable aspect of this camera is that it has a continuous loop type of recording setup. Because of this type of recording, images can be captured both in the pre and post trigger stages.

3. Transient Data Acquisition, Conditioner, and Amplifier System



The third main part of the instrumentation purchased through this research was the Pacific Instruments most advanced high-speed data acquisition system available on the market today. This system consists of 10 independent Model 9355 Transducer Signal Conditioning Amplifiers. This transient data acquisition system is a signal-conditioning amplifier, which uses microprocessors and advanced digital technology to enhance the recording and display of transducer signals. This system also allows for 4096 steps of simulated internal shunt calibration and capabilities for external voltage calibration. Samples rate can be obtained of up to one million samples per second per amplifier. Recording is a continuous lop type recording which allows for pre and post trigger recording capabilities which are independent and therefore different sampling rates can be set for both pre and post trigger positions. The system has internal memory, which allows for storage of data until the system can be returned to a computer command station for debriefing.

4. Various Pressure Gages, Blast Gages, and High-Speed Accelerometers

The transducers purchased are useful for documenting structural loading, structural response, and the high-pressure loading environment during high explosive tests. These include:

- High Pressure Ruggedized Dynamic Response Pressure Transducers with low impedance high output, and very high natural frequency, for pressure blast applications
- Miniature Ruggedized IS Pressure Transducers with high natural frequency.
- Soil Stress Gages for measuring blast induced soil reactions
- Soil Pressure Cells
- Structure Dynamics Pressure Transducers with metal diaphragm
- Piezoresistive Un-Damped Accelerometers

NCERD Research Efforts

The primary objectives of the NCERD are to create new knowledge and to improve our understanding of the explosion environment and blast mitigation technology and to create new and improved structural designs and strategies for protection from explosions. Current research efforts at the center are being directed to the numerical prediction of the damaged zone in a structure under explosion fragments from conventional weapons. Numerical modeling is also being extended for the numerical simulation and modeling to predict the response of the double-wall composite containment vessel under explosion loads.

A brittle damage model for concrete, which can be vectorized for large-scale computer simulation, will be developed in one of the funded projects researchers at the NCERD are currently working on. In this phase of the project, the numerical modeling will be used to predict the evolution of a damaged zone in a bridge section under explosion fragments from conventional weapons. The brittle failure of a bridge section under

explosion fragments involves the initiation and evaluation of localized damage, the transition from continuous to discontinuous failure modes and fragmentation. Future phases of this project will involve the field-testing of the interaction of concrete slabs and explosive fragments.

In another project, the NCERD is proposing to design, build, and demonstrate the performance of a light-weight portable containment vessel for up to 3 lb. of high explosives (HE) and any associated biological or chemical agents. Using innovative computer codes and composite materials, we propose to design, model, build, and test the vessel. Tests will be performed at Fort Leonard Wood, MO, using live explosives. High-speed photography and transient data acquisition systems are very essential instrumentations for the verification of such unique numerical models.

This instrumentation also serves, in general, the objectives and potential research and education goals of the center in evaluating the performance of structures and blast mitigation armors under blast loads and projectile impacts. Specialized pressure transducers and accelerometers are used to characterize the response of structures under blast and ballistic loads.

Following is a brief description of the NCERD and the current funding.

National Center for Explosion Resistant Design

Need: ***Combating terrorism and assuring the security of the United States***

Mission:

- **Create new knowledge of explosion environment and blast mitigation technology**
- **Create improved structural designs and strategies for protection from explosion**
- **Technology transfer**

Research Areas

Blast Mitigation and Terrorist Bombing

- Provide technical support for anti- and counter-terrorist programs
- Develop analytical models and simulation tools to predict the blast environment
- Improve structural design for blast resistance and prevention of progressive building collapse

Accidental Explosions and Explosive Safety

- Provide forensic analysis of explosions resulting from accidental explosions; e.g., petrochemical accidents
- Develop more cost-effective designs for explosive storage and munitions facilities

Force Protection and Military Support

- Conduct tests and evaluation of weapon system effectiveness, and hard target defeat
- Develop improved designs and innovative construction materials for fixed construction
- Develop methods to quickly upgrade blast resistance of temporary housing
- Design auxiliary equipment such as shock isolation devices, blast valves, and blast doors
- Develop a computer test bed and virtual reality modeling tools for military applications

Collaborations

- Partnership with U.S. Army Engineer Center and Fort Leonard Wood, MO
- U.S. Army Corps of Engineers, Waterways Experiment Station
- UM-Rolla, Rock Mechanics and Explosives Research Center

NCERD Current Research Activities

NSF Career Grant ($400k)

- Develop computer test-bed for simulation of blast resistant structures
- Improve education in area of progressive building collapse

DOD/WES ($240k)

- Develop concrete brittle damage model
- Predict damaged zone in bridge section under fragment loading

MU Research Board ($36k)

- Model laminated glass under blast loading
- Test blast resistance of glazing
- Develop standards for explosion resistant window film
- Develop simple predictive models

DOD/WES ($99k)

- Blast retrofit walls
- Analytical and experimental evaluation
- Evaluate various design concepts